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BROOKLYN BOTANIC GARDEN

LEAFLETS

SERIES XVIII BROOKLYN, N. Y., APRIL 2, 1930 No. 1—2

SPRING PLANTING

At this time of the year most of us feel the urge to get out of doors, to dabble with the earth and make a garden. It is a desire that should not be repressed, for, as Francis Bacon said three hundred years ago, "God Almighty first planted a garden: and indeed, it is the purest of human pleasures."

Preparation of the Soil. Success in gardening depends largely on the proper preparation of the soil, whether one has in mind the making of a lawn, the growing of vegetables, or the planting of trees, shrubs, and flowering plants. So in speaking of spring planting one naturally first gives consideration to the problem of adding fertilizer to the soil and tilling it so that it may be in the best possible condition for the growth of plants.

It is generally admitted that stable or barnyard manure is the best all-round fertilizer for the garden. It contains nitrogen, phosphorus, and potash, the three most important elements it is necessary to supply in order to maintain the soil in a state of fertility. Manure usually gives satisfactory results even though no other fertilizers are used. In addition to the plant food it contains, it supplies humus (decayed organic matter) which improves the physical properties of the land and by its decay makes plant foods available that would otherwise remain locked up in the soil. Experience has shown that in order to get the best results from the use of "commercial" fertilizers it is necessary for the soil to be well stocked with humus, and stable or barnyard manure is probably the best form in which this can be added to the soil. The quantity to use depends upon the amount of humus already present in the soil and whether it is planned to use commercial fertilizers in addition. If the soil is deficient in humus, a heavy application is desirable to improve its physical condition; on the other hand, if humus is already present in large quantities it will be economical to reduce the amount of stable manure and supply the chemical elements necessary by using more concentrated fertilizers. Five hundred pounds of manure or a layer two inches thick for a plot containing 400 square feet, will be about right for most gardens. In addition, a dressing of eight pounds of "complete" commercial fertilizer containing nitrogen, phosphoric acid, and potash, obtainable from most seedsmen, could be supplied to advantage (though not absolutely necessary) on the surface after the manure has been dug in, raking it in so as to mix it thoroughly with the top soil.

It often happens that it is not convenient in city gardens to maintain the supply of humus by the use of barnyard or stable manure. In these circumstances a source of supply open to city dwellers is the leaves of street trees when they drop in the autumn if they can be gathered before they have been fouled by automobiles. These should be piled in an out-of-the-way corner of the garden to decay, and mixed with the soil when they are one or two years old. Decay may be hastened by forking over the leaves two or three times during the summer. Garden refuse of all kinds, such as lawn clippings, the leaves and stems of vegetables and flowers may be utilized in the same way. Another means of adding humus is to obtain one of the numerous brands of humus or peat moss obtainable from most seed houses or nurseries. When humus is supplied in the form of the foregoing the amount of "complete" commercial fertilizer used should be greater—about 15 pounds to 400 square feet.

The first step in the actual preparation of the soil is to evenly spread the manure over the surface of the ground. The next process is the spading up of the top soil, or plowing in the case of large areas. Never attempt to work on the soil when it is so wet as to stick to the tools you are using. The soil should be dug up to the full depth of the spade, if the top soil extends that far, at the same time mixing in the fertilizer. All clods should be thoroughly broken up and large stones thrown out. If the ground is covered with grass, the sods should be buried, upside down, at least six inches deep. Don't throw them out to be carted away with the rubbish, for sods are a source of humus and a very valuable ingredient in the soil. The surface should be raked with an iron toothed rake until a finely pulverized seed bed is formed.

Making a Lawn. Having finished with the real hard work—and I assure you, one can get as much exercise from digging the garden as from a round of golf—we will proceed to some of the details of planting. Most people who are interested in a garden want a fine lawn, and some may want to know how to make one. The lawn is important because it gives an element of restfulness in the garden, and because it provides an ideal setting for the flowers.

It is desirable before planting grass seed that the soil be so firmly compacted, that foot marks are barely discernible when the plot is walked upon. If the tramping that the ground receives in the process of pulverizing the surface is not sufficient to do this, it will be necessary to consolidate it by more tramping or by rolling with a light roller. The surface must, however, be loosened with a rake to a depth of half an inch or so just before the seed is sown.

A calm day should be chosen for this work, or there will be great difficulty in distributing the seed evenly. Do the work systematically. Divide the seed into two equal portions. Take one of these, and, starting at one end of the plot, walk back and forth scattering the seed as evenly as possible. Keep the hand low and do not attempt to cover too wide an area at a time. The other half of the seed should be distributed by walking over the plot at right angles to the route travelled in sowing the first portion. This ensures an even distribution of the seed. If a large plot is to be sown, it is a good plan to mark off the area into several equal-sized plots. Divide the seed to correspond, and sow each plot separately. This is very helpful in apportioning the seed evenly all over the area.

When the seed has been sown, the surface should be lightly raked to cover the seed, and then rolled. If a roller is not available, a tamper is a fair substitute for firming the soil about the seeds. A suitable tamper can readily be improvised by sawing about eighteen inches from a plank two or three inches thick. A hole should be bored in the center of this, and a handle of suitable length inserted. A stout broom handle or an old shovel or spade handle can be used for this purpose.

It is not economical to sow grass seed sparingly. When the grass seeds are sown thinly, a splendid opportunity is offered to the weed seeds, of which they do not fail to take advantage. This necessitates much back-breaking work to get the lawn clear of weeds and may require the breaking up of the lawn and a fresh start. On the other hand, a generous sowing of seed ensures a good stand of grass which will choke out many of the obnoxious weeds. The quantity to use is one quart of seed to 300 square feet.

Planting Trees and Shrubs In ornamental gardening, apart from the lawn, we are concerned with the planting of trees and shrubs, the hardy perennials, annuals and bedding plants.

Trees and shrubs are the permanent features of the garden and as such their selection and placing demands thoughtful consideration. Avoid "weedy" trees such as the Carolina Poplar, and soft-wooded Maples. Do not forget the charm of the flowering trees, such as the Dogwood, Japanese Cherries, Magnolias, and the flowering Crab Apples, when making your selection.

When trees and shrubs are received from the nursery, they should be at once unpacked. Remember that the roots must not be allowed to dry. If you are not ready to plant them immediately, heel them in or throw moist soil over their roots and water them if necessary. When planting, make the hole two or three feet wider than the spread of the roots. If the soil at the bottom of the hole is hard, loosen it with a pick or digging fork, and bury some manure. Trim the broken roots with a clean cut just above the break. Place the tree or shrub in position, spread the roots, scatter fine soil amongst them, tamping it in as you do so, being careful to leave no air spaces. Tamping may be done with the feet or with a short pole. Be sure to make the soil firm about the roots, as many amateurs fail through not doing this. The tree should be set one inch deeper than it was when growing in the nursery.

In order to compensate the plant for the unavoidable loss of roots in digging, it is necessary to prune back the top. The amount of pruning necessary varies according to the condition of the roots and the kind of tree or shrub. A good general rule is to cut back three-fourths of the growth of the preceding year.

Roses. Roses are shrubs, of course, and in general the preceding remarks apply to them also. Although fall planting is perhaps to be preferred in this region, spring planting may also be quite successful. The earlier they are planted, once the ground becomes workable, the better. They require a well-drained, deep, rich soil and should be planted so that the "crown" from which the shoots arise is one inch below the soil. Cut out all but the strongest shoots and prune the remaining branches back to four or five buds.

Evergreens. Evergreens are usually received from the nursery "balled and burlapped;" that is, the roots have a ball of earth about them which is held in place with burlap. This ball of earth should be placed in the hole intact, soil filled in around it, and tamped down. It is not, as a rule, customary to prune evergreens at planting time.

Hardy Perennials. The hardy perennials—the old fashioned flowers of our grandmothers—are amongst the most charming and useful of our garden plants. Charming because of the memories they evoke, and useful in many cases, because of their value as cut flowers. If a suitable selection of kinds is made, and if use is made of the spring bulbs (which of course have to be planted in the fall), the perennial border will provide blossoms from early spring until late fall. In March we may expect to see Crocuses and Snowdrops. The tide of bloom is carried along through the months with such favorites as English Daisies, Pansies, Tulips, Bleeding Heart, and Columbine, followed by Iris, Sweet William, Hollyhocks, Sunflowers, and Lilies, until it is at its ebb in November with the hardy Chrysanthemums making a last stand. If you doubt your ability to plan such a garden as this consult one of the many nursery firms specializing in hardy plants who will be glad to help you with plans. Almost all of these hardy plants may be set out at this time, the most notable exception being the Peony, which, to secure best results, should be planted in early fall. In planting perennials, do not forget to make the soil firm about the roots.

Annuals. We must not lose sight of the annuals when planting our gardens. Sweet Peas, Snapdragon, Poppies, Four O'Clocks, Phlox, Mignonette, Asters, and a host of others give wonderful results with very little trouble. Some of these annuals are best when seeded where they are to bloom while others such as Aster, Stock, Petunia and Verbena give a better and longer display if set out as plants that have been raised in greenhouse or cold frame. In planting the seeds avoid planting too thickly because that only makes much work in thinning the seedlings later on. Also avoid planting too deeply. For most annuals one-half inch is ample and in case of the smaller seeds such as Poppy and Petunia, it is sufficient to loosen the surface soil with a rake, scatter the seeds and rake the surface again, afterwards patting down the soil.

The Vegetable Garden. Those who have eaten such vegetables as corn and peas fresh from the garden will know that there is a big difference in flavor between them and the shop-worn kind. So a vegetable plot is a desirable feature of the home garden.

It is a good idea to make a plan on paper before planting the vegetable garden. If space is limited, plan to have a quick maturing crop followed by other quick maturing crops. You will then get the utmost from the space at your disposal. One may plant early peas to be followed, when they are harvested, by Cabbage or Cauliflower; or beets may be planted to be followed later by Bush Beans and so on.

The seed should be sown in drills of suitable depth made with a draw hoe or the edge of a rake, first making the soil as fine as possible. A line should always be stretched as a guide when making the drills, as this insures a straight row and subsequently greater ease in cultivation. Place the seed evenly in the drills, cover with fine soil, and firm with the back of a hoe or the foot.

The rows, when possible, should run north and south. If this is not possible, the low-growing vegetables should be placed at the south end of the plot, so that they will not be shaded by the taller-growing kinds. Perennial vegetables, such as Rhubarb, Asparagus, and Artichoke, should be placed together at one end of the plot, so that they are not in the way when digging or plowing the ground for the next season's work. Crops which are to be followed by other crops later in the season should be grouped together as far as possible, as this facilitates the work and prevents disturbance of the more permanent plantings.

The plan on the next page may provide helpful suggestions. The quantities and kinds of vegetables grown must, of course, be decided by individual preference.

As indicated in the plan, two rows of spinach, and two rows of lettuce may be grown in the space to be occupied later by Egg-plant, Pepper, and Tomato. Similarly two rows of Onion sets may occupy the ground to be used later for growing Beets. Lettuce may be sown directly in the drill where the plants are to mature, or, it may be sown in a seed-bed or shallow box and the seedlings transplanted to their permanent quarters when they are two or three inches high. Cabbage or Cauliflower are best sown in the seed-bed and transplanted later. Unless one has a greenhouse or other facilities for raising tender seedlings, it is better to obtain plants of Tomato, Egg-plant, and Pepper from a seedsman at planting time.

PLAN FOR A SMALL VEGETABLE GARDEN

(North) 20 feet wide (South)

40 feet long

2 ft.	Corn (early)	followed by Corn (late)	
3 ft.	Corn (early)	followed by Corn (late)	
3 ft.	Lettuce	followed by Tomato	
3 ft.	Spinach (spring)	followed by ½ row Egg-plant and ½ row Pepper	
3 ft.	Potatoes		
3 ft.	Potatoes		
3 ft.	Peas (early)	followed by Cauliflower (fall)	
3 ft.	Peas (early)	followed by Cabbage (late)	
3 ft.	Early Cabbage	followed by Celery	
1 ft. 6 in.	Bush Beans	followed by Turnips	
1 ft. 6 in.	Bush Beans	followed by Beets	
1 ft. 6 in.	Beets (early)	followed by Bush Beans	
1 ft. 6 in.	Onions (sets)	followed by Beets	
1 ft.	Carrots (early)	followed by Fall Spinach	
1 ft.	Onion (main crop)		
1 ft. 6 in.	Swiss Chard		
3 ft.	Rhubarb	Parsnip ½ row	Sown with Radishes
1 ft. 6 in.		Parsnip ½ row	

Usually there is not much room in the small garden for such crops as Cucumber, Melon, Squash, etc. When a rich soil, in a sunny position, near a fence, is available, however, they may sometimes be grown to advantage by training them on the fence, thus economizing space.

The following table gives important information for use in planting the vegetable garden.

Time to plant, Depth to Plant, Distance between the Rows and in the Rows, and Quantity of Seed Required for a 100 ft. Row.

Vegetables	*Time to plant*	*Depth*	*Distance between rows*	*Distance in the rows*	*Quantity*
Bean (pole)	May 20 to June 20	2 in.	4 ft.	in hills 4 ft. apart, about 3 seeds to a hill	½ pint
Bean (lima)	May 20 to June 20	2 in.	4 ft.		
Bean (dwarf)	May 10 to Aug.	2 in.	1 ft. 6 in.	3 in.	1 pint
Beet	April to Aug.	1½ in.	1 ft. 6 in.	4 in.	2 oz.
Cabbage (early)	Feb. indoors; plants set out in Mar.		3 ft.	2 ft.	1 oz. will produce 2000 plants
Cabbage (late)	May, indoors; plants set out in July		3 ft.		
Carrot	April to July	1 in.	1 ft.	3 in.	1 oz.
Cauliflower (early)	Feb. indoors; plants set out in Mar.		3 ft.	2 ft.	1 oz. will produce 2000 plants
Cauliflower (late)	May, indoors; plants set out in July		3 ft.		
Celery	Mar. indoors; plants set out in early July		3 ft.	9 in. to 1 ft.	1 oz., about 3000 plants
Corn	May 10 to July 10	2 in.	3 ft.	2 ft.	½ pint
Egg-plant	Mar. indoors; plants set out in late May or early June		3 ft.	3 ft.	1 oz. will produce 600 plants
Lettuce	April to Aug.	½ in.	1 ft.	9 in. to 1 ft.	½ oz.
Onion (seed)	April to May	1 in.	1 ft.	4 in.	1 oz.
Onion (sets)	Mar. 15 to May 15	2 in.	1 ft.	2 in.	
Parsley	April	½ in.	1 ft.	6 to 8 in.	¼ oz.
Parsnip	April	1 in.	1 ft. 6 in.	6 in.	½ oz.
Peas (dwarf)	Mar. 15 to June 15 and Aug. 1 to 20	2 in.	2 to 3 ft.	2 in.	1 quart
Peas (tall)	May 15 to June 15 and Aug. 1 to 20.	2 in.	4 to 6 ft.	3 in.	1 quart
Peppers	Mar. indoors; plants set out in late May or early June		3 ft.	2 in.	small package
Potatoes	April 15 to June	4 to 6 in.	3 ft.	12 to 18 in.	½ peck
Radish	Mar. to Sept.	½ in.	1 ft.	2 in.	1 oz.
Spinach	Mar. and Sept.	1 in.	1 ft. 6 in.	4 in.	1 oz.
Swiss Chard	April	1 in.	1 ft. 6 in.	6 in.	1 oz.
Tomato	Mar. indoors; plants set out in late May or early June		3 ft.	3 ft.	1 oz. will produce over 1000 plants
Turnip	April and Sept.	½ in.	1 ft. 6 in.	6 in.	½ oz.

MONTAGUE FREE.

NOTICES

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BROOKLYN BOTANIC GARDEN
LEAFLETS

SERIES XVIII BROOKLYN, N. Y., APRIL 30, 1930 No. 3

FERTILIZERS FOR CITY GARDENS*

It is generally admitted that stable or barnyard manure is the best all-round fertilizer for the garden. It contains nitrogen, phosphorus, and potash, the three most important elements necessary to supply in order to maintain the soil in a state of fertility. Manure usually gives satisfactory results even though no other fertilizers are used. In addition to the plant food contained, it supplies humus (decayed organic matter) which improves the physical properties of the land and by its decay makes plant foods available that would otherwise be locked up in the soil. Experience has shown that in order to get the best results from the use of "commercial" fertilizers it is necessary for the soil to be well stocked with humus, and stable or barnyard manure is probably the best form in which this can be added to the soil. Barnyard manure may be applied in the spring or fall. If applied in the fall, fresh manure may be used, first spreading it over the surface and then digging the plot so as to bury the manure as deeply as possible. If application is deferred until the spring, it should be partly decayed, as in this form the plant foods it contains are more quickly available for the use of the crop. If the manure is thoroughly decayed and in a finely pulverized condition it is a good plan to first dig the ground, leaving the surface rough, and then spread the manure, afterwards raking thoroughly so as to mix it with the surface soil. The quantity to use depends upon the amount of humus already present in the soil and whether it is planned to use commercial fertilizers in addition. If the soil is deficient in humus a heavy application is desirable to improve its physical condition; on the other hand, if humus is already present in large quantities, it will be economical to reduce the amount of stable manure and supply the chemical elements necessary by using more concentrated fertilizers. Commercial vegetable growers use anywhere from 10-100 tons of manure per acre, the amount generally used being 20-30 tons. For the small garden from 300 to 500 pounds for a plot containing 400 square feet, or spread on the surface from one to three inches thick will be suitable. If manured in the fall in this manner a dressing of 6-8 pounds of "complete" commercial fertilizer, obtainable from most seedsmen, could be applied to advantage in the spring (though not absolutely necessary) as a surface dressing, raking it in so as to mix it thoroughly with the top soil.

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* This LEAFLET is a reprint, with revisions and additions, of Series VI, No. 8, 1918.

It often happens that it is not convenient in city gardens to maintain the supply of humus by the use of barnyard or stable manure. In these circumstances the growing of a cover crop to provide green manure is a convenient method of supplying humus. Another source of supply open to city dwellers is the collection of the leaves when they drop from the street trees in the autumn, provided that they have not been fouled by passing automobiles. These should be piled in an out-of-the-way corner of the garden and mixed with the soil when they are one or two years old. Decay may be hastened by forking over the leaves two or three times during the summer. Garden refuse of all kinds, such as lawn clippings, the leaves and stems of vegetables and flowers, may be treated in the same way. This latter method sometimes has the disadvantage of returning to the soil the spores of disease organisms that may be present, thus providing a source of infection for future crops. Another means of adding humus is to obtain one of the numerous brands of humus or peat moss obtainable from most seed houses or nurseries. When humus is supplied in the form of green manures or leaves, the amount of "complete" commercial fertilizer used should be from 12 to 18 pounds for every 400 square feet.

Chicken manure, which is sometimes available, is one of the most concentrated of the organic fertilizers. It can be used to good advantage to supplement a dressing of barnyard manure, at the rate of 20 pounds to 400 square feet. As the plant foods it contains are quickly available, it should be applied in the spring as a surface dressing, thoroughly mixing it with the soil. If this fertilizer is available in a sufficient quantity to warrant its being used as a base for a complete fertilizer it should be used at the rate of 40-50 pounds to 400 square feet, supplemented by 6-8 pounds of acid phosphate and 6-8 pounds of unleached hardwood ashes. The chicken manure must not be mixed with the other ingredients before application, or loss of nitrogen will result. Chicken manure, previous to use, should always be stored under cover to prevent leaching. A good method, which facilitates future handling, is to place it in barrels or boxes in layers with an equal amount of dry soil.

Sheep manure, while not so concentrated as the preceding, can be used in much the same way by increasing the quantity about 50%.

Bone meal is an important source of phosphoric acid; it also contains some nitrogen. The coarser grades act rather slowly and the food materials contained are not immediately available. It is used at the rate of 12 to 15 pounds to 400 square feet. Acid phosphate, prepared from phosphatic rock, is another important fertilizer supplying phosphorus. It is used at the rate of 8-12 pounds to 400 square feet.

Wood ashes contain potash and lime and small amounts of phosphoric acid. It is a fertilizer especially valuable on clayey soils, as it improves their physical condition. It is considered to be a valuable fertilizer for all fruits—apples, peaches, etc.—and for crops that are grown for their roots, such as beets and carrots. Use 20 to 40 pounds to 400 square feet.

Sulphate of potash and muriate of potash contain potash in a more concentrated form than the preceding, and are used at the rate of about 3-5 pounds to 400 square feet.

Nitrate of soda is a very quick-acting fertilizer and is useful for stimulating the growth of plants in early spring when the nitrogen content of the soil is usually low. It is especially valuable for crops that are grown for their leaves, such as cabbage, Swiss chard, spinach, and lettuce. Use 1½ to 2 pounds to 400 square feet. As nitrate of soda is readily soluble in water, it should not be applied much before planting time or it will leach out of the soil before the crop can use it. The writer prefers to use this fertilizer as a top-dressing after the plants have started their growth, applying it at the rate of ½ ounce to a square yard at intervals of about three weeks. All lumps must be crushed before using and care must be taken not to allow any to lodge on the leaves of the crop. Great caution must be exercised in the use of this fertilizer, especially in connection with crops that are grown for their roots or fruits, such as beets, carrots, peas, beans, and tomatoes, as it may result in the production of leaves at the expense of the part desired for use. Sulphate of ammonia and dried blood are other important sources of nitrogen.

Acid phosphate, bone meal, nitrate of soda, and wood ashes are not what are known as "complete" fertilizers. That is, they do not provide nitrogen, phosphorus, and potash. It is customary to use them in combination with other fertilizers or to supplement a complete organic fertilizer which may have a deficiency of one or more of the three elements most necessary as plant foods. It will be noticed, for instance, that wood ashes is part of the formula with chicken manure as a base. Bone-meal could be used to take the place of the acid phosphate in this formula.

Lime is an indirect fertilizer in that it helps to put the soil in good physical condition, provides the slight alkalinity desirable for most vegetable crops, and assists in making inert plant foods available. It is used in the form of ground limestone, or of air-slaked lime, at the rate of 20 pounds to 400 square feet.

It should be borne in mind that lime, or any fertilizer containing lime, such as wood ashes, must not be applied so as to come in contact with any organic manure or it will result in loss of nitrogen.

All concentrated fertilizers can be best applied by first digging or plowing the ground, leaving the surface rough, then scattering the fertilizer, afterwards raking to mix with the soil. Bulky manures, such as undecayed barnyard or stable manures, leaves, and cover crops should be dug in as deeply as possible.

MONTAGUE FREE.

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BROOKLYN BOTANIC GARDEN

LEAFLETS

SERIES XVIII BROOKLYN, N. Y., MAY 14, 1930 NO. 4

THE PRINCIPAL GROUPS OF FOSSIL PLANTS

The six transparencies of fossil plants which are described in this Leaflet and which have been installed in the Conservatories of the Brooklyn Botanic Garden, depict the plants of certain groups as they appeared throughout successive ages. Each picture does not represent the plants of any given geological age, chiefly for the reason that these periods were of such long duration and the transition from one period to another was so gradual that we are often not sure what plants and animals were living together at the same time. Our fossil records are so incomplete that we can rarely determine with accuracy when a given plant or animal first appeared and when it died out. Therefore, each transparency represents several types of fossil plants belonging to a given group, with the setting of an imaginary landscape, for the purpose of securing a more realistic effect. For each transparency only well known and characteristic fossil plants have been selected. The following observations and descriptions apply to these various transparencies and the fossil groups which they represent.

I. Algae Algae are generally considered as the primary ancestors of plants. Long ages of life in the water must have preceded land life. Algae are in general not adapted for preservation as fossils, and their supposed remains often can not be definitely classified. The abundance of Algae in early geological ages is implied by the teeming animal life of these early periods which must have depended upon them. The various groups of Algae were doubtless present even before the Cambrian period.

II. Early Land Plants The interesting fossil *Psilophyton* was first discovered in the Gaspé Peninsula by the geologist Dawson in 1859—the year of the publication of the "Origin of Species." It has later been found in Europe, and is hardly different from *Rhynia* from Scotland, now well known. These plants, about eight inches tall, had no leaves nor roots, but an underground rhizome. Well preserved stomata indicate that they were land plants. Their general structure assigns to them a place near the primitive ancestors of land plants. *Asteroxylon,* slightly larger, with small, spiny scales, is somewhat like the modern *Psilotum* and *Tmesipteris,* which also have small leaves and no roots. *Hyenia,* with jointed stems, suggests the Horsetail group. These fossils are found only in the Devonian period.

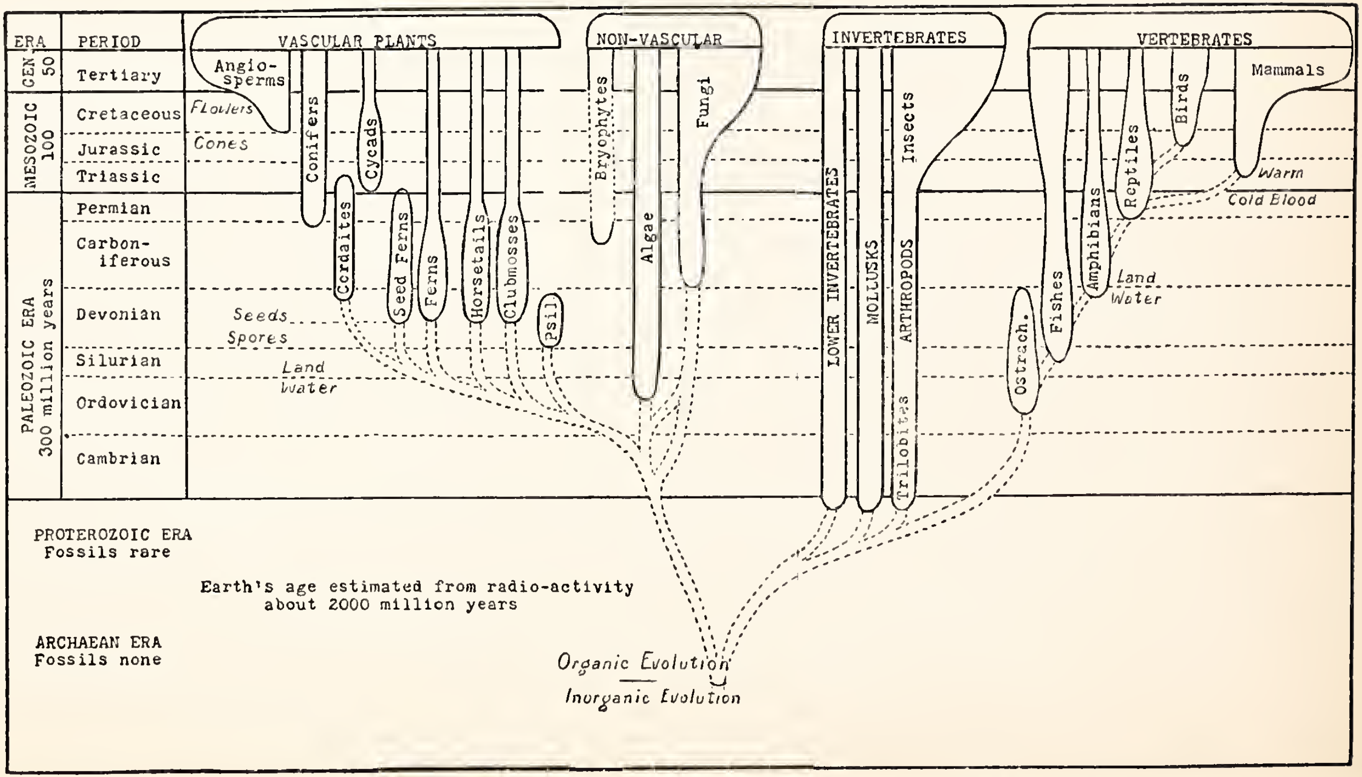

Diagram illustrating the dominance of plant and animal groups in the geological periods.

The important groups, Fungi and Mosses, are slightly represented as fossils. Lichens and Liverworts may well have been among the earliest of land plants.

III. Tree Clubmosses The present day Clubmosses are the diminutive relatives of the great tree Clubmosses of former ages. *Protolepidendron* is a small Devonian tree of Europe and America. *Bothrodendron,* larger, has also very small leaves. The numerous species of *Lepidodendron,* well known great trees of the Carboniferous and Permian, are widely distributed. They have dichotomous branching, conspicuous leaf scars spirally arranged, and often large cones. The *Sigillarias* are also great trees, often with conical bases. They have no or few branches, with terminal Yucca-like leaves, vertically arranged. The group of the small water plants of the present time known as Quillworts resembles the *Sigillarias* in various ways.

IV. Horsetail Group This group has jointed, ribbed stems. *Pseudobornia* is a peculiar small tree or perhaps prostrate plant, found by Nathorst in Devonian strata on Bear Island south of Spitsbergen. It has very finely divided leaves, usually four in a whorl, and large cones. *Sphenophyllum* is a widely distributed, low plant, somewhat like the modern *Galium* or bedstraw. It has long, slender stems with swollen nodes and leaves usually in whorls of six. The medium sized trees of *Calamites* were widely distributed from the Carboniferous to the Triassic.

V. Ferns and Seed Ferns Differing from clubmosses and horsetails, the ferns and higher plants are characterized by "foliar gaps." That is, there is an opening in the vascular tissue just below the point of departure of the leaf from the stem. Usually the leaves are larger than in the lower plants: it is as if the stem gave up a part of the tissue to make a large leaf. The early ferns have more open venation than modern ones. There are also changes in the position of the spore cases and a tendency to have fewer spores in modern ferns. Seed ferns are really gymnosperms, but as it is often uncertain whether fronds do or do not go with seeds, the ferns and seed ferns are usually grouped together.

VI. Gymnosperms. These differ from the lower plants in having seeds instead of spores, or rather they have both spores and seeds. Spores are simple bodies, usually of one cell; seeds are complex bodies, containing a dormant young plant or embryo. The differentiation of spores into two sizes—large and small—is a first step in the direction of seed formation. In the Gymnosperms, the small spores are brought by the wind near the large spores. The large spores remain attached to the mother plant, where they germinate and after fertilization by the male element developed from the small spores, ripen into seeds containing an embryo. In this way the seed-bearing plants take care of the next generation better than the spore-bearing plants do. This difference is much like that between the higher and lower animals.

Seed Ferns and *Cordaites* appeared in the Devonian period; therefore seed-bearing plants are almost as old as any known land plants. When the parallel-veined leaves of *Cordaites* were first studied they were thought to belong to the Monocotyledons. It is now known that they are Gymnosperms, perhaps nearest to *Ginkgo* or *Agathis*. *Cordaites* trees grew to about 100 feet with trunks attaining a diameter of two feet. They did not branch until near the top; the leaves are up to three feet long and more than a foot wide. There are two kinds of cones: pollen-bearing and seed-bearing.

The genus *Baiera* probably also resembled *Ginkgo*, but the leaves were more divided. *Walchia* of the Upper Carboniferous and Permian was perhaps somewhat like *Araucaria*.

Living Cycads are represented by nine genera, chiefly in the southern hemisphere. In the Mesozoic Era there appear to have been two lines, the *Williamsoniales*, rather slender forms perhaps related to the seed ferns, and the *Cycadeoidales*, with thick trunks and a few branches; that is, their habit resembled the modern Cycads. These fossil groups usually have pollen and seeds on the same cones, suggesting Magnolia flowers, while modern Cycads are dioecious.

Angiosperms This group is not included in the transparencies, because its fossils differ so little from plants of the present time. They begin in the lower Cretaceous. The early forms, all trees and shrubs, include Poplar, Beech, Walnut, Magnolia, Laurel, Plane-tree, Holly, *Aralia* and *Viburnum*. It is interesting that many genera had a more extensive, in particular more northern, geographical distribution in former periods. Thus Hazel, Hornbeam, Magnolia, Tupelo and others grew in Greenland and Spitsbergen.

Fossils indicate that herbaceous flowering plants are more recent than woody plants. The former exhibit usually more specialized floral structures than woody plants, and it is probable that they represent adaptations to survival through a winter season. The evolution of the flowers of angiosperms doubtless runs parallel to that of insects. In general we see that successive changes in the plant world have preceded changes in the animal world, which directly or indirectly depends on plants.

ALFRED GUNDERSEN.

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BROOKLYN BOTANIC GARDEN

LEAFLETS

SERIES XVIII BROOKLYN, N. Y., JUNE 4, 1930 No. 5

THE PLANT WARDS OF NEW YORK STATE

On April 10, 1930, with the approval of Governor Franklin Roosevelt, New York State officially increased the number of its plant wards by an amendment to the State Conservation Law (Chapter 384). For several years the Conservation act has included four species of flowering plants which were named as specifically protected on State or other public land; viz., trailing arbutus (*Epigaea repens*), mountain laurel (*Kalmia latifolia*), flowering dogwood (*Cornus florida*), and the pink lady's slipper or moccasin flower (*Cypripedium acaule*). To this list there have now been added five additional flowering plants and one particular fern species, together with "ferns of any kind" growing on the lands of the people of the state or on any public property. As will be seen from the copy of the present law, printed at the end of this LEAFLET, the six additional species definitely mentioned are as follows:

Fringed gentian (*Gentiana crinita*)

Closed gentian (*Gentiana Andrewsii*)

Yellow lady's slipper, both species
(*Cypripedium parviflorum* and *C. pubescens*)

Showy lady's slipper (*Cypripedium reginae*)
Hart's tongue fern (*Scolopendrium vulgare*)*

With respect to the hart's tongue fern, the law refers definitely only to its natural habitats, as "from any location in Onondaga or Madison counties." It is further stated that "possession by any person of the whole or part of a plant which subdivision two of this section is intended to protect shall be presumptive evidence that the same was unlawfully taken by the possessor." The complete statement of the law is quoted at the end of this article. Anyone interested in examining the Connecticut law on wild plant conservation may obtain a copy of a Leaflet containing a reprint of that law by addressing the Secretary, Brooklyn Botanic Garden.

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* Phyllitis Scolopendrium is also commonly used as the scientific name.

It is gratifying to be able to assign credit for this latest amendment to the New York law to the Syracuse Botanical Club, an organization with a long history of active plant study. Leadership in the formulation and original presentation of the amendment was furnished by Mrs. John Church, the club president. New York State has a particular interest in guarding, so far as possible, the remaining plants of what may be called the rarest fern species in the United States, the hart's tongue, which is found naturally in only four localities in North America: in Onondaga and Madison counties in New York State; in Tennessee; and in Ontario, Canada.

The citation of this fern, which, in itself, is more strange and odd as a fern than beautiful, may be considered a recognition of the importance of protecting our biological inheritance as such. Not because of its beauty, nor because of any possible economic value does this plant species deserve special recognition, but solely as a rarity, a relic of the past, which was in danger of complete destruction. Unlike the passenger pigeon which formerly thrived in a wide range of localities, and was wiped out because of its economic value, the hart's tongue is so particular in its environmental demands that there seem to be only a few half-shaded limestone talus slopes on which it exists naturally on this continent. The recent transformation of one of these localities at Jamesville, N. Y., itself a remarkable geological formation, into a huge rock dump, was a matter for great regret. The illustrations show the change which was wrought, during 1929, by a great industrial development, in one of the best locations for this fern. (Figures 1 and 2.)

As a means of offsetting in part the gradual diminution in numbers of the hart's tongue, the Brooklyn Botanic Garden has carried on an experimental distribution of young greenhouse-grown plants in the hope that some might be planted out in acceptable new localities and thus initiate new colonies. A comprehensive check-up of results is now under way and will be reported upon later this year. At the same time, additional spore cultures have been started for further distribution, when the plants are large enough. A number of earlier Leaflets and other articles on plant conservation have been published and will be forwarded, on request, (by the Secretary of the Brooklyn Botanic Garden) to anyone interested. Furthermore, a set of lantern slides, representing the protected species together with a number of additional species, is now available for loan from the Brooklyn Botanic Garden slide collection. Members of the staff will be glad to accept invitations from schools, garden clubs, etc., to present the subject of plant conservation in detail.

Ralph C. Benedict.

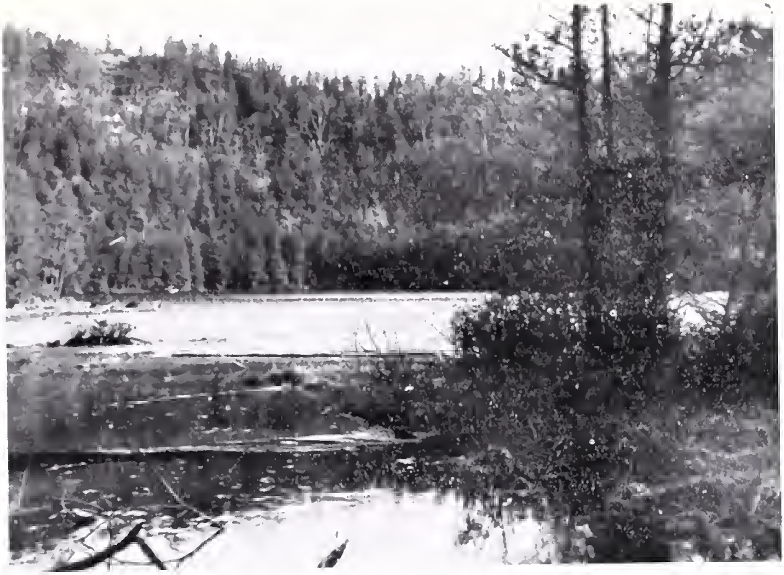


Figure 1. View of East Green Lake, near Jamesville, N. Y., early in 1929. The lake lies in a narrow horse-shoe shaped valley, with slopes and cliffs about two hundred feet higher. The peculiar formation represents an old glacial plunge basin, over which a real Niagara once poured. The hart's tongue fern was formerly common on the slopes in the background. (Photograph by R. C. Benedict.)

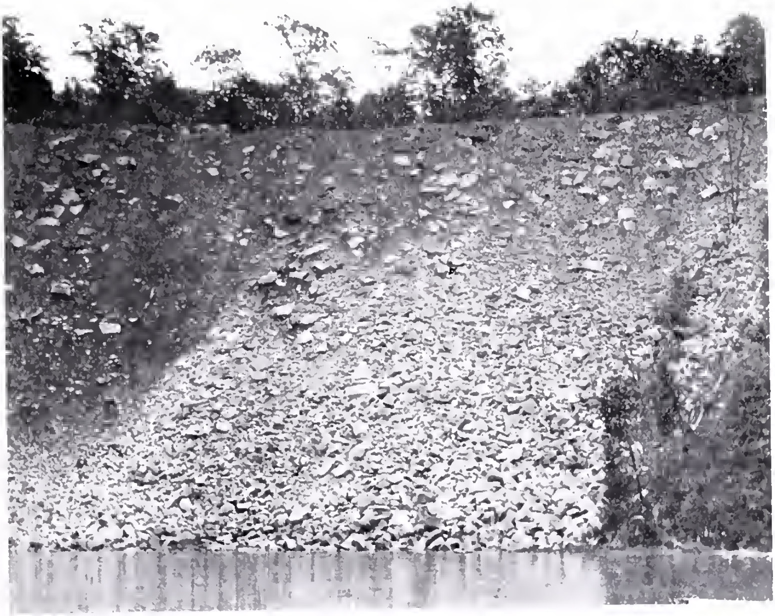


Figure 2. Section of the slopes shown in the previous figure, a few months later. A railroad spur has been run to the cliff edge and now torrents of waste limestone pour over the edge, gradually to fill in the one hundred feet deep plunge basin washed out by ancient waters. (Photograph reproduced by permission of the Syracuse Post-Standard.)

PRESENT PLANT CONSERVATION LAW OF NEW YORK STATE

LAWS OF NEW YORK

Chapter 394

AN ACT to amend the penal law, in relation to taking, injuring and destroying certain trees or wild flowers.

Became a law April 10, 1930, with the approval of the Governor. Passed, three-fifth being president.

The People of the State of New York, represented in Senate and Assembly do enact as follows:

Section 1. Subdivision two of section fourteen hundred and twenty-five of the penal law is hereby amended to read as follows:

2. Cuts down, girdles or otherwise injures or destroys, a fruit, shade or ornamental tree standing on the lands of another, or takes, picks, plucks, severs, carries away, removes, or injures, in a manner to kill or cause to die, or destroys any plant, shrub, tree or vine, of any wild or cultivated trailing arbutus (Epigaea repens), flowering dogwood (Cornus florida), mountain laurel (Kalmia latifolia), or pink lady's slipper, or any of the moccasin flowers, including Cypripedium acaule, Cypripedium pubescens, Cypripedium parviflorum, Cypripedium reginae or either Gentiana crinita or Gentiana Andrewsii, or ferns of any kind growing on the lands of the people of the state, or in any street, highway, public place or park belonging to or under the control of any county, city, town or village; or willfully digs up, takes or carries away the hart's tongue fern (Scolopendrium vulgare) from any location in Onondaga or Madison counties; or

2. Such chapter is hereby amended by adding a new subdivision, at the end of subdivision fifteen of such section, to be subdivision fifteen-a, to read as follows:

15-a. The conservation commission and the state council of parks, within their respective jurisdiction, their several employees, the state police and all peace officers, are charged with the duty of enforcing subdivision two of this section. Possession by any person of the whole or part of a plant which subdivision two of this section is intended to protect shall be presumptive evidence that the same was unlawfully taken by the possessor.

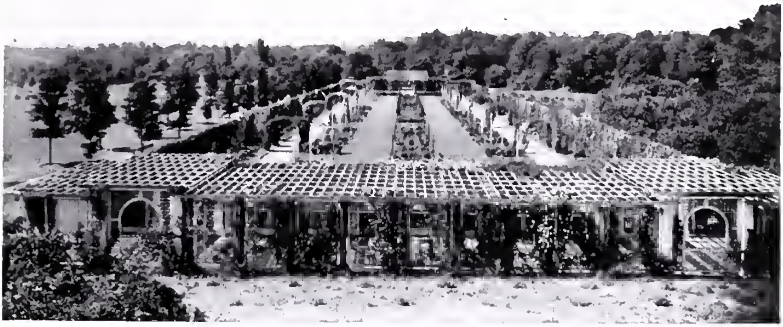
3. This act shall take effect immediately.

SEP 17 1930

THE ROSE GARDEN

OF THE

BROOKLYN BOTANIC GARDEN



GENERAL VIEW OF THE ROSE GARDEN

BROOKLYN BOTANIC GARDEN
LEAFLETS

Series XVIII Brooklyn, N. Y., Sept. 10, 1930 No. 6

THE ROSE GARDEN OF THE BROOKLYN BOTANIC GARDEN

Our Rose Garden was made possible through the gift of $15,000 by Mr. and Mrs. Walter V. Cranford. The design was prepared by Mr. Harold A. Caparn, the consulting landscape architect of the Botanic Garden. Work on the necessary grading was started about the middle of June, 1927. In the fall, nearly one thousand rose plants were set out and in the following spring two thousand additional bushes were planted. The garden now contains three thousand roses in about six hundred and fifty varieties. Where shade conditions are such as to be unsuitable for the growth of roses, rhododendrons and plants of a similar nature are set out.

The Rose Garden occupies an area of about one acre west of the Esplanade. It is 500 feet long and 93 feet wide. It is enclosed by a Doric pergola at the north end and by a wooden trellis supported on concrete posts on the other sides. Towards the south end of the garden a rectangular mound extends across almost the whole width of the garden. This provides a vantage point from which to view the garden as a whole. Surmounting this elevation is a lattice-work pavilion supported by concrete posts and wooden Doric columns. Two short pergolas connect the pavilion with east and west entrance gates. North of the pavilion the garden forms a rectangle, 353 feet long and 93 feet wide. South of the pavilion the area is roughly in the shape of a right-angled triangle with a convex hypotenuse. The whole garden is bounded by a wide border containing wild roses with their horticultural derivatives not included in the central beds. These, with the rose covered fence behind, serve as a frame or setting for the rest of the garden, and give a definiteness and dignity to the composition that is lacking in the ordinary collection of bedding roses. It is difficult to assemble a collection of wild roses, and our exhibit of species is still far from complete, but it is hoped that in the near future we shall have a large representation of roses of this type.

Next to the boundary border comes a walk which extends around the whole garden. Inside the walk the triangular area south of the pavilion contains three beds of irregular shape set in turf. The southernmost bed contains Sweetbrier roses and the hybrids known as the Penzance briers developed by Lord Penzance from the common Sweetbrier, *Rosa rubiginosa.* The bed on the east is occupied by roses of historical interest such as "York and Lancaster," the Damask rose, etc. The bed on the west is temporarily occupied by the variety, "Mary Wallace," the scrambling growths of which are pegged to the earth.

North of the pavilion, the central grass panel is occupied by three rows of beds, each ten feet wide and about fifty feet long. The center row of beds contains Hybrid Perpetual roses with a border of Polyantha roses. The side beds contain Noisette, Tea, Bourbon, and China and Hybrid Tea roses with the major portion of the area given over to the popular Hybrid Teas. These roses are arranged in chronological sequence according to the year of their introduction, beginning with the oldest roses at the north. Wherever possible, the parent roses of these various races are exhibited at the beginning of the sequence. This method of planting was adopted with the object of enabling visitors to study the development of the rose in the many groups represented and to observe the improvement that has been accomplished throughout the years by hybridization and selection. Thus, in the Hybrid Tea group, for example, the planting starts in the northernmost beds with "La France," the oldest Hybrid Tea rose, introduced in 1867, and finishes in the southernmost bed with such recent introductions as "Miss Rowena Thom," "Kardinal Piffl," and "Joyous Cavalier."

Entering the garden from the north we find in the western row of beds of the central grass panel, first, a small representation of Noisette roses (most of these roses are not hardy with us), followed by Tea roses and Hybrid Teas, and, at the south, about one-half of a bed devoted to single Hybrid Tea roses. In the eastern row of beds, we start off with Bourbon roses, followed by China roses, and Hybrid Teas, finishing up at the extreme south with the well-known rose, "Soleil d'Or," and other Pernetiana roses. The content of the southernmost beds of the three rows in the central panel is constantly changing, because it is in these three beds that the newest introductions are grown.

The walks are spanned by ten metal double arches which support climbing and rambler roses. A row of ornamental concrete posts, thirty in all, connected by chains, extends down the center of the beds on two sides of the central panel. These are for the support of rose festoons. Tall cedar posts for strong growing pillar roses are placed at intervals along the boundary border and shorter posts for the weak growing pillar roses are placed along the sides of the central row of beds. Space is provided for roses grown as "standards" of Hybrid Perpetuals, Hybrid Teas, and climbing varieties. On the terrace slopes around the pavilion, roses of the varieties, "Max Graf" and *wichuraiana* are grown as ground covers. The bank north of the pergola is planted with rambling and climbing roses in several varieties, which are to be allowed to grow at will and are expected to completely cover this bank. It will thus be seen that roses of practically every type are grown in this garden and that they are displayed in all the forms common in horticultural practice. The various structures of the rose garden—fences, pergolas, pavilion, etc.—were designed for the display of climbing roses in as many ways as practicable.

In preparing for planting, the whole area of the garden was worked over and eighteen inches of good topsoil provided. This was accomplished by using the topsoil from the walk that extends all around the garden to supplement that of the beds, and removing subsoil from the beds to fill in the walk. One hundred and fifty cubic yards of cow manure were mixed in with the topsoil.

The Botanic Garden authorities are much gratified at the number of visitors seen in the garden with pencil and paper noting the names of roses that take their fancy—an obvious indication that a labelled collection of roses in a public garden is useful and appreciated.

Quoting from the 1927 annual report of the Director of the Botanic Garden: "This Rose Garden is planned not only to be a thing of beauty (as are most rose gardens), but, in harmony with the plan of the Botanic Garden as a whole, to be an educational feature. Wild species are included as well as horticultural varieties and the latter are arranged so as to illustrate the historical development of the modern horticultural varieties of Hybrid Teas, Hybrid Perpetuals, and other groups of roses."

MONTAGUE FREE.

NOTICES

The Garden may be reached in the following ways: Flatbush Avenue trolley to Empire Boulevard; Franklin Avenue and Lorimer Street trolleys to Flatbush Avenue; St. John's Place trolley to Sterling Place and Washington Avenue; Ninth Avenue, Union Street, Vanderbilt Avenue, and Smith Street trolleys to Grand Army Plaza and Union Street; Brighton Beach Express, Broadway (B.M.T.) Subway to Prospect Park (north exit). From Pennsylvania Station, Manhattan, take Broadway-Seventh Avenue Subway to Eastern Parkway-Brooklyn Museum Station. From Grand Central Station, Manhattan, take Lexington Avenue Subway, changing at Nevins Street, Brooklyn, to Broadway-Seventh Avenue Subway, getting off at Eastern Parkway-Brooklyn Museum Station.

The Garden is open free to the public daily, from 8 a. m. until dark; on Sundays and holidays from 10 a. m. until dark. The Laboratory Building, containing the Library, Herbarium, and offices, is open daily (except Sundays), from 9 a. m. until 5 p. m. (Saturdays, 9-12). The Conservatories are open April 1-September 30, 10 a. m.-4:30 p. m. (Sundays, 2-4:30); October 1-March 31, 10 a. m.--4 p. m. (Sundays, 2-4).

Entrances—On Flatbush Avenue (1) near Empire Boulevard, and (2) near Mt. Prospect Reservoir; on Washington Avenue, (3) south of Eastern Parkway, and (4) near Empire Boulevard; on Eastern Parkway, (5) west of the Museum building.

The street entrance to the Laboratory Building is at 1000 Washington Avenue, between Eastern Parkway and Empire Boulevard and opposite Crown Street.

The LEAFLETS are published weekly or biweekly from April to June, and September to November, inclusive, by The Brooklyn Botanic Garden, 1000 Washington Avenue, Brooklyn, N. Y.

Ten numbers (occasionally more) constitute an annual series. Copies are supplied free to teachers on request, and to members of the Garden. Subscriptions are 50 cents per year, or 5 cents a number; double or triple numbers (8 or 12 pages) at the same rate.

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BROOKLYN BOTANIC GARDEN

LEAFLETS

SERIES XVIII BROOKLYN, N. Y., OCT. 29, 1930 NO. 7-8

CABBAGES IN THE CLASSROOM*

The cabbage in its time has played many parts. Today, when its place in the cuisine is rather plebeian, there is little indication of past glories or of capacity for more than a most subordinate position on the bill-of-fare. It is the purpose of this LEAFLET to suggest, however, that the cabbage is by no means "through"; that its long record of activity in the kitchen and garden is just the basis which has prepared it to serve in a higher position in the classroom.

How often in the past the cabbage may have served as the jester in the petty autocracy of classrooms! How many pedagogues have pleased themselves, if not their pupils, by a regularly recurrent venture into the facetious, a reference to the possible vegetable quality of the heads of their charges? Probably this form of pedagogic witticism might be traced back to the earliest period of instruction. As a matter of fact, the epithet, "cabbage head" is tautological, for it appears that the word, cabbage, derives from the Celtic "*Cab*" or "*Kab*," meaning "head," an interesting indication of the antiquity of the solid form of this vegetable.

But cabbages might readily appear in the schoolroom in an entirely serious way. The Latin class might be asked to translate Cato's panegyric on cabbages in his "*De re rustica*," written about 200 B. C. There he declaims regarding the value of cabbage as an appetizer if taken before a meal, of its acceleration of digestion when eaten during a meal, and as an incitement to thirst—a weakness of old Cato's—when taken afterward. As an appetizer, he suggests eating five leaves, spiced with vinegar. After the meal, if one has dined well, another five cabbage leaves will make one feel as if he had had nothing to drink, so that he may drink as much more as he wishes ("*bibesque quantum voles*"). Other cabbage classics may be found in the writings of Cicero, Columella, Pliny, and doubtless, other Romans. From Theophrastus, "Enquiry Into Plants," (English translation by Sir Arthur Hort. Vol. II, p. 85), the following quotation is taken: "Of cabbage three kinds are distinguished, the curly-leaved, the smooth-leaved, and thirdly, the wild form [wild radish]. The wild form has a small round leaf, it has many branches and many leaves, and further a sharp medicinal taste; wherefore physicians use it for the stomach. Between the other two kinds there seem also to be differences, inasmuch as one of them bears no seed or only inferior seed. In general the curly-leaved kind has a better flavor than the smooth and it has larger leaves." It is indicated as probable that the "wild form" referred to is a different species, some form of radish.

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*This LEAFLET was prepared in connection with a study of cabbage types which has been carried on at the Brooklyn Botanic Garden during 1929 and 1930, largely with the idea of making these common vegetables more familiar and usable in teaching. Living material of upwards of thirty kinds is being grown in the experimental plot.

Will Durant, in his "Story of Philosophy" quotes a section from Plato's "Republic" in which the philosopher mentions cabbages as one desirable element in a vegetarian diet. "Of course they will have a relish—salt, and olives, and cheese, and onions, and cabbages or other country herbs which are fit for boiling; we shall give them a dessert of figs, and pulse, and beans, and myrtle-berries, and beech-nuts, which they may roast at the fire, drinking in moderation. And with such a diet they may be expected to live in peace to a good old age, and bequeath a similar life to their children after them."

Horticulturists who have delved into the past ascribe the origin of cauliflower to the island of Cyprus, with an age-long use in Egypt and other Mediterranean countries.

Another very distinctive variety which must have had long history, and is known sometimes as "Walking Stick Cabbage" and "Jersey Tree Kale", hales from the island of Jersey, south of England. It may grow to a height of 15 ft., and the ripened stems, according to the Encyclopaedia Brittanica, are used for canes, and for small rafters in thatch roofed cottages.

With Plato and Cato as authorities, it is obvious that the cabbage tribe is of ancient lineage, and it is suggested that history classes may well take into account the possible significance of these plants, as typifying green vegetables, in the diet of nations. Deforestation, and the invasion of malarial germs through captured slaves are cited as important factors in the decline of ancient Greece. Soil exhaustion is accounted an important contributory cause in the decline of Rome. Today we know that pellagra, a vitamin-deficiency disease, which green vegetables will alleviate or prevent, afflicts a considerable portion of the United States. McCollum, analyzing racial diets, finds the explanation of the ability of the over-crowded millions of south-eastern Asia to continue a bare existence in the fact that they have learned to grow and use that combination of foods which can be raised most economically and at the same time includes a large proportion of leafy vegetables, and therefore vitamins. A comment by Dr. L. H. Bailey,[1] is interesting in this connection. "In parts of the oriental countries, the brassicas afford a staple rather than an incidental article of food. It is not unlikely that they supply nitrogenous elements and vitamines, in foliage and seeds, that have played an important part in the persistence of the people." Is it not more than probable that the nutritional factor has been fundamentally important in more than one historic period?

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[1] Bailey, L. H. The cultivated brassicas. Gentes Herbarum 1^2:56. Ithaca, N. Y. 1922.

That cabbages have long had a place in human history is indubitable, but the exact history and genealogy of the scores and hundreds of different types known today is a matter of uncertainty. When Cato talked about cabbage leaves, he used the Latin word, "*brassica*," to signify the plant, and this word has continued in use, in some form or other, ever since. Today, the cabbage species is known scientifically as *Brassica oleracea*, a name given by Carl Linné, in the eighteenth century. The main types of vegetables included in this species are each given a separate varietal designation. Thus, the typical cabbage is *B. oleracea capitata*, the third Latin name meaning "headed," and represented in a vernacular Italian name for cabbage (*cappuccio*). Kohl rabi is *B. oleracea caulo-rapa*, in which the third term is appropriately translated, "stem turnip;" Brussels sprouts is *B. oleracea gemmifera*, or "bud bearing;" and one of the kales is *B. oleracea acephala*, meaning "not headed."

Dr. Bailey, attesting an interest of "over thirty years in the botanical identity of the cultivated coles and mustards," finds them "the most baffling plants I have ever studied." He agrees with Sir David Prain that "the evidence points to an Asian origin" for all the cultivated brassicas, originally, but that the immediate ancestral form of "the kales, heading cabbages and cauliflowers" is the "*Brassica oleracea* of the cliffs and shores of Europe."

There seems to be general agreement among horticulturists who have examined the historical references most carefully that the ancient Romans had at least three distinct forms: a leafy, non-headed *kale* type, more or less like the wild species; a loose-headed *bud* type, perhaps like modern Savoy cabbage; and some fasciated, "*flowering-shoot*" variety of the broccoli or cauliflower character. Only Brussels sprouts is probably to be accounted a parvenu in this family, with a family history in Lowland Europe which one authority estimates at not more than one hundred and fifty years, although another extends it back to the thirteenth century because of a Dutch reference to "*Spruyten*."

Biologically, there are so many points of possible interest in these cabbage forms, even for elementary classes, that it is difficult to select a few as most significant. The difficulty of tracing their exact ancestry has already been indicated. It is usually assumed that all of the dozens of diverse sorts have arisen from a wild form which today is found along the European coast from Denmark and southern England southward and along the Mediterranean. While this is usually accounted the wild cabbage, there is some doubt about it. The Standard Cyclopedia of Horticulture figures the wild form as having deeply lobed leaves, but plants grown from seed originally obtained from English sources by the Bureau of Plant Industry showed no lobing at all. They closely resemble ordinary cabbage, differing most obviously in not heading. (Fig. 1.)

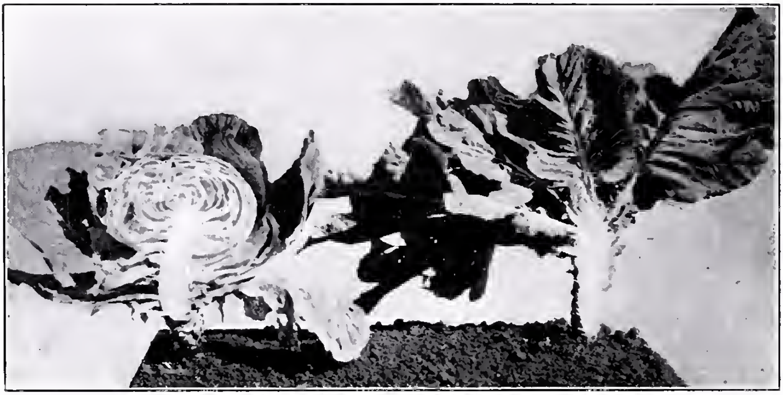

Figure 1.—Sections of a regular headed cabbage and a non-heading, possibly wild, type.

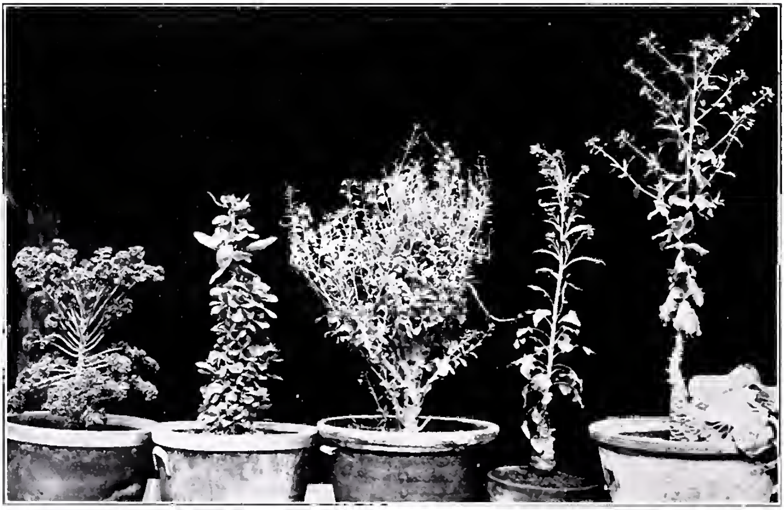

Figure 2.—Second-season stages of five forms, four in actual flower: kale, Brussels sprouts, sprouting broccoli, kohl rabi, and cabbage, with a market head alongside for comparison.

Regardless of genealogical uncertainty, ordinary cabbage furnishes an excellent large-scale example of a *terminal resting bud,* readily available for class dissection. (Fig. 1.) Brussels sprouts may be used to demonstrate *lateral buds.* (Figs. 2 and 4.) Broccoli and cauliflower constitute illustrations of *flower stems and buds* thickened for storage. Kohl-rabi, which looks like a green turnip, is obviously a *stem*, with its leaves and leaf scars. (Fig. 4.) Again, the cabbage is an excellent example of a *biennial* plant. The large bud we use as a vegetable is formed in the first year. For flowering specimens and seed, such bud plants must be continued over winter and given another season of growth. The flowering specimens of the several types of cabbage illustrated in figure 2, had been potted up from the field in the fall, and rested in a cool greenhouse for some months. There they gradually lost their basal leaves until, in January, 1930, the second year, the buds started into active growth and shot up several feet in a few weeks, breaking out into sulphur-yellow flowers of the four-petalled, cruciate, mustard type. Sprouting green broccoli (Figs. 2 and 4) is not so definitely biennial, as it opens its flowers regularly in the first season, and even regular cabbage is liable to "bolt" (run to flower ahead of time) under the climatic conditions of England.

Considered as material for the study of "variation under domestication," the cabbage group offers a wealth of material, a good variety of which is easily obtainable in the market place. Whatever their exact wild origin, there is no doubt of a close relationship between the diverse types; the short-stemmed cabbage "bud" type, wrinkled or smooth, red or green; the tall, separate-leaved kales (Fig. 3) and collards, either smooth or extraordinarily ruffled, and in different colors; the stem types of kohl-rabi, and the "marrow" cabbage, little grown in the United States; and the thickened flowering shoots

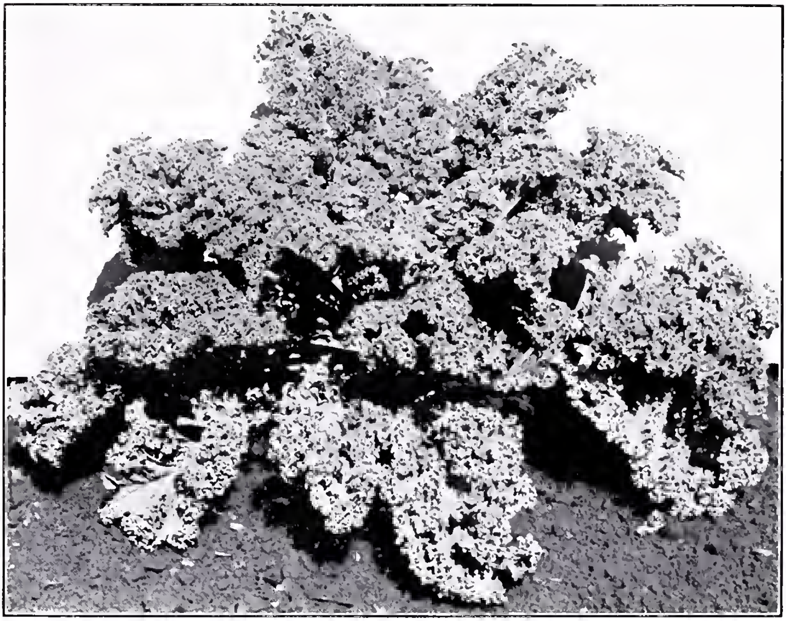

Figure 3.—Scotch curled kale represents a leafy type, in which the leaf is extremely ruffled. This is probably the hardiest form.

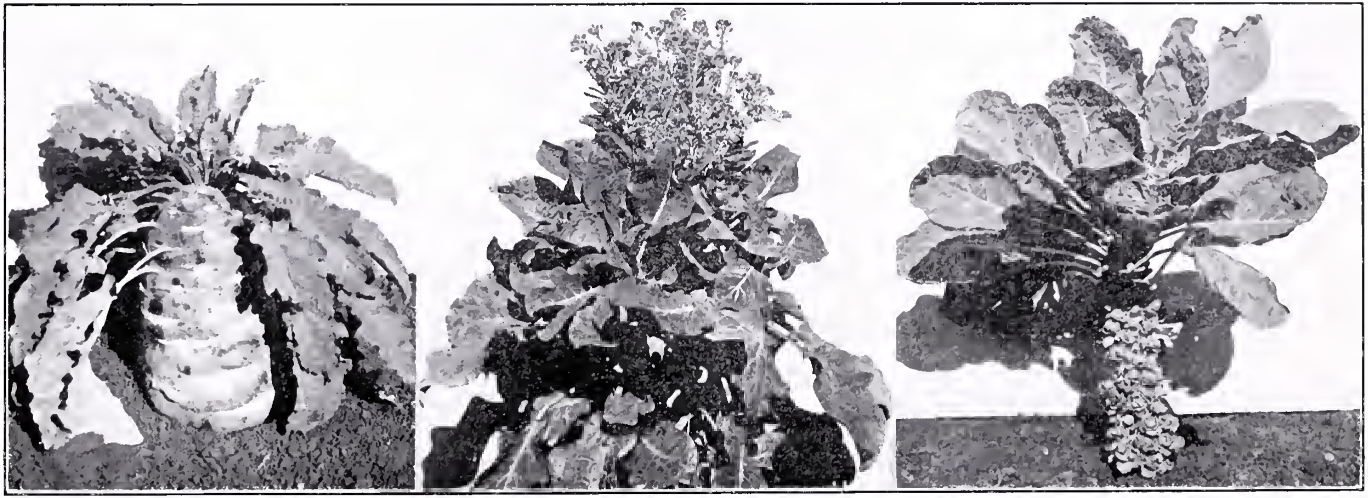

Figure 4.—The left-hand figure shows a mature plant of purple kohl rabi. The unusual shape is due to the completed growth. The second specimen, sprouting broccoli, has also passed beyond the edible stage into actual flowering. The third, Brussels sprouts, is approximately normal.

of the broccolis and cauliflowers, with their different colors. These cabbage types serve to re-emphasize the fact that many remarkable new forms had been produced even before the beginning of recorded history, and that the name of successful plant breeders has been legion.

What a field for experimental hybridization this *Brassica* complex offers! Besides the numerous forms of *B. oleracea*, which hybridize readily with each other, there are a number of additional species in the same genus. Several other wild species are known in the Mediterranean region which would possibly be fertile in crosses. Indeed, it may well be that some prehistoric accidental hybridization of two wild species was the original incitement to the wealth of variation which the cultivated forms display today, as the great Swiss botanist, de Candolle, believed.

There are half a dozen additional species which furnish economic plants. *Brassica nigra* is the source of black mustard, and *B. alba* of white mustard, together with tons of oil every year. Both these are annuals. Two Chinese species, which form rather dense buds, are extensively grown as vegetables, and can usually be purchased in the markets of Pell and Mott Streets, New York. Ordinary white turnip, yellow turnip, and rape are *Brassica* species, and might cross with cabbage, cauliflower, and the rest. A cross between cabbage and radish, the latter a different mustard genus (*Raphanus*), has several times been made.

A rather extensive hybridization experiment was carried out over twenty years ago by Arthur Sutton, a member of the English horticultural firm of Sutton and Sons, Reading, and reported on before the Linnaean Society in 1908. Over eighty distinct crosses were attempted. In those experiments, it was found not possible to produce hybrids between plants of the turnip species and the cabbage group. On the other hand, there seemed to be no difficulty whatever in obtaining hybrids between any pair of the cabbage group. In some of the crosses, "mule" hybrids were obtained, that is, plants incapable of producing seed. Mr. Sutton obtained an amazing series of mixed and intermediate types. One, combining the characteristics of ordinary cabbage and Brussels sprouts, namely, with a large terminal "cabbage" bud and numerous smaller lateral "sprouts," was introduced as a new vegetable, but subsequently discontinued owing to failure to appeal to the public.

More recently, Dr. A. B. Stout has shown that the flowers of cabbages may vary greatly in capacity for self fertilization according to a definite periodicity. According to his findings, the early flowers are persistently self-sterile, but easily fertilized when foreign pollen of an allied variety is used.

During the past spring, a casual attempt at hybridizing kohl rabi and sprouting broccoli was made with the plants shown in the illustration (Fig. 2). On the stigma of a broccoli flower the protruding stamens of a kohl rabi flower were gently rubbed. Although it had been flowering for months continuously, without setting fruit, the three cross-pollinated flowers of the broccoli plant promptly set fruit, which finally yielded some thirty seeds. When planted, five good seedlings were obtained which at this time show clearly their biparental origin. The broccoli characters are indicated chiefly by large leaves, while a bulbous swelling on the stem represents the kohl rabi ancestry. It is not beyond the bounds of possibility that a series of crosses might unite in one plant the features of several of the diverse species. Picture, for example, a synthetic vegetable, with a fleshy turnip root, an erect stem bearing lateral Brussels sprouts, and a terminal head, either cabbage, or cauliflower in type! That such a general purpose plant would be economically important is very doubtful, but that some similar combination of now separated characteristics might be experimentally developed by hybridization is far from idle speculation.

Finally, the value of cabbages for experimentation in plant physiology may be mentioned. Seedlings of the various types are easily grown, and are tolerant of transplanting. A group of these seedlings recently afforded fine demonstrations of two important though much overlooked plant reactions.

On a humid day, when presumably evaporation could not readily take place, it was noted that all the seedling leaves were regularly beaded with globular drops of extruded liquid, borne at the ends of marginal teeth. The same demonstration can easily be repeated by placing potted seedlings under a bell jar and providing an abundance of moisture and a saturated atmosphere. Under circumstances in which ordinary water excretion by evaporation through stomata (transpiration) cannot take place, probably almost all plants are able to excrete water as liquid through special water pores or hydathodes, an obligate method in aquatic plants. This phenomenon seems to be entirely overlooked by high school text books, and by many elementary college texts in botany as well. That dew is not necessarily water of condensation but may often be principally this liquid plant excretion comes as an unexpected revelation to most biology students.

Three potted kale seedlings gave one of the best demonstrations of *etiolation* I have ever seen. Left in a dark room under a dripping faucet from Friday to Monday, each developed one or two new leaves with petioles several times normal length, and with leaf blades inversely small. The stem had lost all evident chlorophyl and the internodes were considerably lengthened.

References to cabbages as material for the biology classroom might be indefinitely extended. In dietetics, McCollum would probably give them almost as high a rating as did Cato, over two thousand years ago, although he would couch his encomiums in different terms, referring to the antiscorbutic value of raw cabbage, the complementary value of the amino-acids of cabbage proteins, the roughage value of the cellulose fiber, and the necessity of the minerals. Plebeian though they be in their modern associations, these cabbage types are commended to the attention of the reader as offering abundant illustrative material for elementary biology, while at the same time connected with esoteric mysteries worthy of the most erudite historical and scientific research.

R. C. Benedict.

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SCHOOL NUMBER

BROOKLYN BOTANIC GARDEN

LEAFLETS

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FORMS AND FUNCTIONS OF ROOTS

This LEAFLET is the third and last in the series on the forms and functions of the vegetative organs[1] of seed plants which has been prepared primarily for the assistance of the teachers and students of botany and biology who come to visit the outdoor plantations and the conservatories of the Brooklyn Botanic Garden.

I. ORDINARY ROOTS

1. *General characteristics.* In *form* the typical root is cylindrical, although tapering somewhat and coming to a point at its tip. The primary root, or the first root developed in the germination of the embryo, grows vertically downward, and branch roots or secondary roots assume more or less horizontal positions. The *extent* of the root system of many plants, both as regards depth attained and volume of soil included, is often quite surprising. A honey locust seeding (*Gleditsia triacanthos*), thirteen weeks after germination of the seed, although with a stem only nine inches high, produced a very widely spreading root system that extended well down into the fourth foot of soil. Sweet corn has a wonderfully developed root system which occupies rather thoroughly over 200 cubic feet of soil. The rapid *rate of growth* of some roots is also remarkable. In many of the common grasses the rate of growth in length is over ½ inch a day. Roots of the white potato, when they begin their vertical descent, may elongate at the rate of one inch a day for a period of two weeks or more. The main roots of corn sometimes grow two to two and one-half inches a day for three or four weeks.[2] In *color,* roots vary, the prevailing hue being a brown, at least in those portions a little distance from the tip. Yellow roots are not rare, as e. g. those of the gold thread, *Coptis trifolia,* (which has yellow root-stocks as well) and the yellow-root *Zanthorhiza apiifolia. Sanguinaria canadensis,* the blood-root, as its name implies, has red roots, and the bittersweet, *Celastrus scandens,* has roots of an orange hue. The roots of herbaceous annuals die out at the end of the season along with the remainder of the plant, and those of herbaceous perennials are probably formed anew each season, since these plants are continually forming new stems or stem struc-

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[1] Graves, Arthur Harmount. Forms and functions of leaves. Brooklyn Bot. Gard. Leaflets 14 $^{8-12}$; 1-8. 1926.

——. Forms and functions of stems. Brooklyn Bot. Gard. Leaflets 17 $^{8-12}$: 1-16. 1929.

[2] Weaver, John E. Root development of field crops. pp. 47, 48. McGraw-Hill Book Co., New York and London. 1926.

tures underground, for which roots are needed. In the case of woody perennials (trees and shrubs) the roots, like the stems, become hard and woody, and continue to increase in girth from year to year. Their internal structure is then very similar to that of the woody stem, but a careful microscopic examination will reveal the characteristic arrangement and structure of the water-conducting cells of the root when it was still young. These are to be found near the center of an old woody root. Unlike stems, roots are not divided into joints or nodes, nor are their branches developed with any regularity or at any particular points. Sometimes, as in the young roots of the bean, the branch roots appear in four rows, obviously due to the presence of four vascular bundles in the interior. However, in general, the branching is quite irregular, and seems mainly to be stimulated by the relative amounts of moisture or nutrients present in the soil. Like stems, roots with few exceptions, such as turnips and other storage roots, possess what we have called the *unlimited type of growth,* i. e. they do not cease to grow when they have reached their characteristic size and shape as do leaves, but only when external conditions are unfavorable for their further advance. The growth in this case, as in the stem, is localized mainly in the apical portions, where a group of cells (comprising the *growing point*) is capable of constant division. All of the cells comprising the primary tissues of the root take their origin from this little group of actively dividing cells. The *root cap* is composed of layers of loosely attached cells, also products of the cells of the growing point, but thrown off in an outward or distal direction. Further, ordinary roots are clothed with *root hairs* which are disposed about the root in a zone which begins at a little distance above the growing point. These hairs are cylindrical extensions of surface cells of the root. At first appearing as small swellings on the outer walls of the surface cells, they grow gradually to a maximum length and then die off. The zone of root hairs thus formed, as well as the region of the growing point and a region between these two areas where the newly formed cells are stretching out to their mature size, may all be readily seen with the naked eye, the whole structure being white and of a fresh appearance, thus contrasting strongly with the older, discolored portions of the root where the outer tissue consists of layers of cork. Roots ordinarily give rise only to roots, and only in rare cases do they bear buds or shoots. Some of these exceptions are: sweet potato, rose, willow, osage orange, silver poplar, beech, sumac.

We may summarize as follows the characteristics of ordinary roots:

1. Growth downward in the soil.
2. Cylindrical in form.
3. Color mostly brown, but occasionally yellow or red.
4. Texture firm in herbs; hard in woody plants.
5. Not divided into nodes and internodes.
6. Irregular branching.
7. Give rise to roots only (with exceptions).
8. Tips of roots show root cap, growing point, "region of elongation", and root hairs.
9. Unlimited type of growth (with exceptions).

2. *Functions.* Ordinary roots of seed plants perform two major functions which are obviously of great importance: *first,* they absorb water and nutrient salts from the soil; and *second,* they provide a means for anchoring the plant in position in the soil. These functions are fully explained in current botanical textbooks, and so it is unnecessary to go into details here. It may be remarked, however, that these functions are fairly well localized in the root—the soft white apical portions serving as the absorbing organs, their surface area being many times increased for this purpose by the root hairs, and the older portions with their complex of branches extending through the soil, serving mainly as the supporting or anchoring organs.

II. ADVENTITIOUS ROOTS

As to their *place of origin* one may divide all roots into two classes: the ordinary type which traces its origin to the lower end of the hypocotyl in the embryo, and the adventitious sort which arises directly on stems, more often at the nodes, and also occasionally from leaves. Adventitious roots perform a number of special functions, as will be shown later. Because of their widespread occurrence, we have given them a position coördinate with ordinary roots, and except for one or two features of minor importance their characteristics agree closely with those of ordinary roots.

In the development of the root system of the cereals, adventitious roots play a large part. Soon after the primary root appears on germination of the seed, two or more lateral roots appear on the stem above the primary root. On account of their mode of origin, these are really adventitious[3]: together with the primary root and branches they constitute the "*primary root system.*" Later, other adventitious roots arise still higher up on the stem, and these with their branches constitute the "*secondary root system.*"[4] The latter, in the case of the cereals and other grasses with strong, thread-like or fibrous roots, composes the larger part of the root system. Thus the primary system is largely, and the secondary system entirely, of adventitious origin.

III. SPECIAL FUNCTIONS OF ROOTS

a. Storage of Water or Food. In some plants the roots become considerably enlarged and fleshy, containing stores of water and food, the latter principally in the form of sugar or starch. Often it is the primary root which is thus distended, sometimes to an almost globular form, as in some varieties of turnip or beet; or to a lesser extent as in the carrot or dandelion. In the latter cases it is called a *tap root.* However, not all tap roots necessarily serve as storage organs. In the hickories and most of the oaks the long tap roots extend deep into the soil, and for this reason these species are difficult to transplant. Sometimes side roots are included in this thickening process, as in the sweet potato or dahlia, and here the roots are designated as *fascicled.*

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[3] Van Tieghem, Ph. Traité de botanique. pp. 203, 4. Paris, 1891.

[4] Weaver, John E. l. c. p. 33.

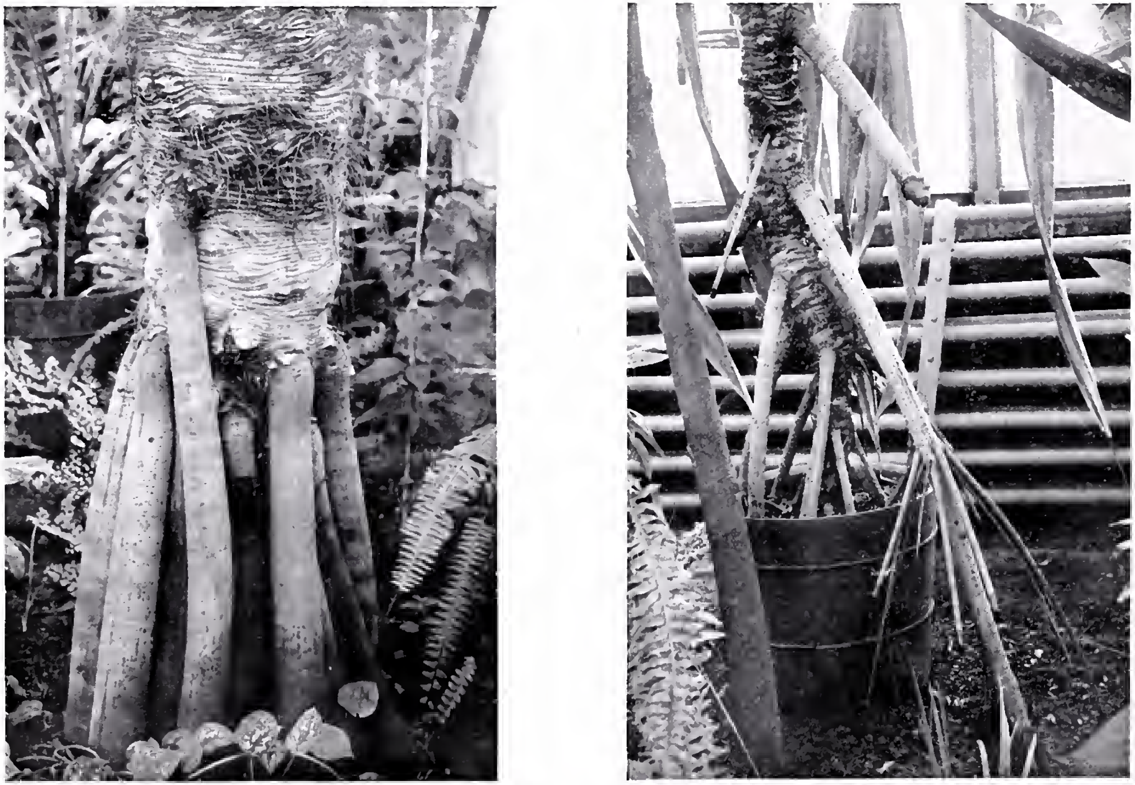

Figure 1.—Two species of screw pine growing in the conservatories of the Brooklyn Botanic Garden and showing well developed prop roots. Left, the common screw pine (*Pandanus utilis*). At about the center of this picture is a young root covered by a root cap, and above it a root just starting to emerge. Right, the Veitch screw pine (*P. Veitchii*). Three new prop roots forming above, each covered by a root cap—see text. Note the straight rows of warty projections.

b. Aeration. The "*knees*" of the bald cypress (*Taxodium distichum*) roots, which grow upward to the surface of the swamp water in which the cypress trees live, are obviously the result of some reaction to the environment, and are popularly supposed to function as breathing organs, swamp water being known to be deficient in oxygen. When the bald cypress grows on *terra firma* the "knees" do not develop.[5]

At the Brooklyn Botanic Garden the individuals of this species in the Japanese Garden are growing on the shore of the lake, that is, on dry land, and the absence of knees in their case is, therefore, what one would expect. Air roots or *pneumatophores* develop in large numbers from the mangroves growing on the muddy, water-soaked flats and lagoons of the Bermudas, Florida, South America, etc.[6]

c. Prop Roots. In various monocotyledons, roots grow out from the erect stem at a little distance from the ground. Usually unbranched while they are still in the air, they develop a profuse branch system on reaching the soil. These specialized adventitious roots are obviously of great advantage to tall monocotyledons, for, as is well known, the latter can increase little in diameter and are in danger of becoming top-heavy. A ring of roots issuing from the stem near its base and taking firm hold in the soil acts as a prop for such plants. The screw pine (*Pandanus utilis*, fig. 1) which may be seen near the front of the Economic House of the Conservatories, nearly opposite the entrance to House 12, furnishes a splendid illustration of these prop roots. It is interesting to note the size and character of the root cap shown at the tip of one of the younger roots in the figure, of almost the size of an after dinner coffee cup, truly of enormous dimensions, speaking in terms of an ordinary root cap. In another species of screw pine (*P. Veitchii*) diagonally across the path from the first, the first prop roots entered the wooden box in which the plant is growing, but later ones, originating higher up on the stem, have reached out beyond the bounds of the box and sunk themselves in the ground below.

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[5] Watson, W. D. The development and function of the so-called cypress-"knees", together with a short consideration of the natural habitat of the tree. Proc. Am. Assoc. for the Adv. of Sci. *39* (1890): 329-330. (abstract). 1891. This author states that by cultivating seedlings with varying degrees of moisture, the knees may be produced or withheld at will.

The knees may be formed in the following ways:

1. Any root may extend upward to the surface [of the water], at various angles after which it turns downward and grows deep into the soil. Active growth begins at the upper or exposed part of the root and the continuation of this growth produces a knee which extends vertically up into the air.
2. Any root tip may grow vertically up through the soil or water until exposed to the air. This portion in the air begins at once to thicken up, sends down new lateral roots as supports and thus forms a "knee."
3. The knees are formed from protuberances developed on the upper side of already well grown horizontal roots.

For internal anatomy of the knees see Lotsy, J.P. The formation of the so-called knees on the roots of the *Taxodium distichum* Richard. Johns Hopkins Univ. Studies from the Biol. Lab. 5: 269-277. 4 fig. 2 Pl. 1893.

[6] For an account of the *pneumathodes*, or aerating roots in the oil palm, see Yamplosky, Cecil. The pneumathodes on the roots of the oil palm (*Elacis guineensis Jacq.*) Amer. Jour. Bot. 11-502-512. 2 Pl. 1924.

Of the nature of props also are the roots of the Banyan tree, *Ficus Benghalensis,* a native of southern India. Growing downward from the spreading branches, they serve as additional trunks, so that from a single trunk to start with, eventually a small forest is formed. A specimen of this tree will be found on the east side of the Economic House. Although young, this already shows adventitious roots high up on the trunk and branches.

Cissus sicyoides, a tendril-climbing plant of tropical America and a relative of the grape, will be found in the Conservatories in House 4. just at the entrance door to the Economic House. Long, threadlike adventitious roots descend from its stems overhead, reaching the bench below or often the floor of the greenhouse, and brush against the passerby like the dangling ropes used on railways to warn brakemen of an approaching bridge. That these organs are true roots and not stems is proved by their internal structure, as well as by the fact that they produce no buds. On reaching the ground they branch profusely, but never develop shoots there. On account of their slender nature they can not strictly be classified as prop roots, although possibly in their native habitat they may assume greater thickness.

d. Absorptive Air Roots. Many of the tropical members of the orchid family, as well as some of the arum family, grow on the trunks and branches of trees. These plants develop a peculiar type of root which absorbs water readily by a process essentially the same as that which takes place when we soak up water with blotting paper, i. e. by capillarity. Except for their tips these absorptive air roots are a silvery white color, due to the air present in an enveloping layer of dead cells, the *velamen.* It is through these cells that the water travels by capillarity to the interior of the root where by osmosis it penetrates to the conducting tissue. Besides absorbing water the velamen may hold it for some time, and thus is of advantage for water accumulation as well as for water absorption. In House 2 a large number of the orchids may be seen provided with these air roots. It is interesting to note that in many cases they seem to have lost their geotropic tendency, being oriented in various directions.

f. Climbing Air Roots. Adventitious roots which are of advantage for anchoring climbing plants onto upright supports are of fairly common occurrence. The vanilla (*Vanilla planifolia*) (Figure 2), a member of the orchid family, which may be seen winding about a support near the entrance door to the Economic House, develops one root at each node. The pepper (*Piper nigrum*), which will be found climbing up the rubber plant (*Ficus elastica*) on the east side of the Economic House and also opposite the entrance to House 10, sends out from one to three roots at each node. In House 8, which is devoted entirely to tropical monocotyledons, species of *Philodendron* with their handsome, velvety leaves also illustrate well the development of adventitious roots for climbing. In all these cases the adventitious roots arise at the nodes, but in the ceriman (*Monstera deliciosa*) which clambers over the rockwork at the west side of the pool in the Economic House, the roots emerge at other places along the stem. Here, as described in the LEAFLET on stems[7], the stout, tortuous

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[7] Graves, A. H. l. c. p. 6 and figure 1.

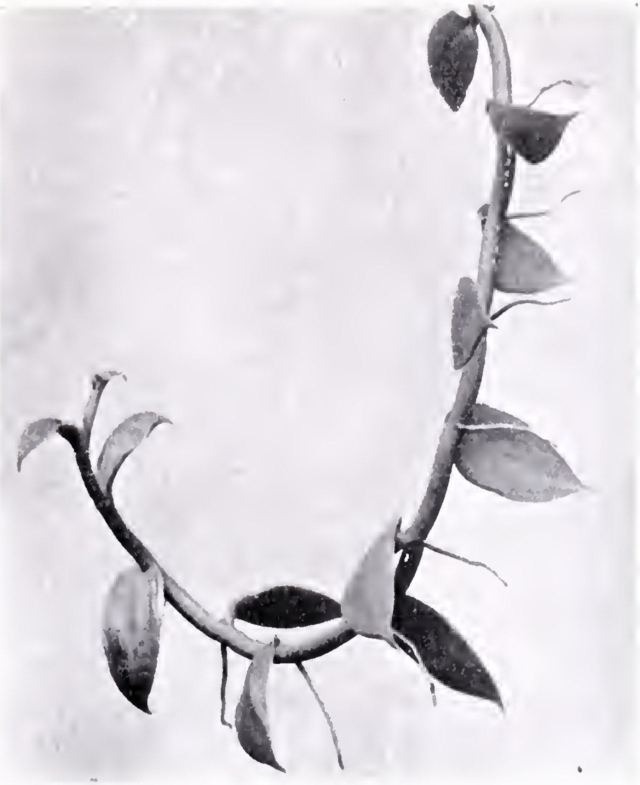

Figure 2.—Vanilla plant in conservatories of Brooklyn Botanic Garden, showing adventitious roots, of advantage for climbing.

stems also contribute their part to its climbing habit. In the English ivy (*Hedera helix*) growing near the path at the north end of the Children's Garden, the adventitious roots appear in great numbers along *any* part of the stem; likewise in the poison ivy (*Rhus toxicodendron*), which may be seen in a boxed enclosure, climbing up a red gum tree on the border mound south of the Rock Garden. In old specimens of poison ivy occurring in our forests, the sinuous, rope-like trunks, fastened tightly to the bole of the tree, are clothed with these adventitious roots so thickly as to seem as if covered with a felt of coarse, wiry hair.

g. Serving as Foliage. Although portions of roots exposed to the light often take on a greenish tinge due to the formation of chlorophyll, notably in some of the epiphytic orchids (House 2), in only rare instances do the roots become definite photosynthetic organs. The epiphytic orchid *Taeniophyllum* has green, flattened and ribbon-like aerial roots which have taken over the functions of the leaves, the latter being reduced to mere scales without chlorophyll.

h. Contractile Roots. Some so-called stemless plants like the dandelion possess, in reality, a very short thick stem, whose apex is about level with the surface of the soil. Since this stem must increase to a slight extent from year to year, the result would be that in a few years it would inevitably project above the surface of the ground—a condition which never happens on account of the contractile nature of the root. By a gradual contraction of the latter a pull is exerted on the stem which therefore sinks deeper and deeper into the soil. So it is with a plant like the crocus, which each year forms a new corm on top of the old. Special contractile roots, developed from the base of the new corm, grow downward, and by contracting pull the new corm down into the soil. It is interesting to note that when once the corm has descended to a certain depth the contraction of the so-called "pull roots" ceases.[8]

i Spines. Occasionally roots become modified to form thornlike growths.[9] The thornlike or warty projections appearing in straight rows on the prop roots of the species of *Pandanus* shown in figures 1 and 2, are said to contain the rudiments of branch roots which in case of injury to the main root may grow out and take its place.[10]

j. Haustoria. The dodder (*Cuscuta* sp.) which may be seen during the growing season twining about plants in the Ecological Garden, opposite the Rock Garden, derives its nourishment from its host by means of curious root-like organs or haustoria (literally *drinkers*). These organs may be developed wherever the stem of the dodder touches the stem of the host plant. By means of enzyms they penetrate the tissues of the host plant and then attach themselves to the vascular bundles from which they absorb nourishment.

k. Mycorrhizas. A mycorrhiza (literally *fungus root*) is a root[11] of one of the higher plants which is encased in the hyphae or vegetative threads of a fungus, and whose tissues as well harbor the hyphae. The larger roots of many of our forest trees, notably the oaks and pines, bear innumerable mycorrhizas, which appear as small, club-like growths along the main root. Many botanists believe that these mycorrhizas, at least in some cases, are advantageous to the tree, enabling it to absorb its nutrients from the soil more readily; others explain them as a case of parasitism on the part of the fungus. Further investigation is needed on this point. In the case of the orchid mycorrhizas, recent investigation points to the conclusion that the fungi are not essential, providing that necessary organic solutions are present in the soil. If these are lacking the fungi evidently make them available by digestive action.[12]

ARTHUR HARMOUNT GRAVES.

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[8] Recent studies on the mechanism of this contraction show that in *Brodiaea lactea*, a member of the lily family with a corm similar to that of the crocus, the shortening of the specialized contractile root developing from the new corm is accomplished by a combination of growth and turgor conditions in the cortical cells. During the process there is an actual shortening and broadening of these cells, followed by their complete collapse. Smith, Frank H. The corm and contractile roots of *Brodiaea lactea*. Amer. Jour. Bot. *17*: 916-927. 1930.

[9] Goebel K. Organography of plants. Part II, p. 288. English ed. London, 1905.

[10] Warburg, O. Pandanaceae, in Engler's Pflanzenreich. 3 Heft (IV 9), p. 6. 1900.

[11] The term has been restricted by some authorities to the fungus alone.

[12] See Knudson, L. Physiological study of the symbiotic germination of orchid seeds. Bot. Gaz. *79*: 345-379. 1925.